CONGRESS OF THE UNITED STATES
CONGRESSIONAL BUDGET OFFICE

CBO

Options for Fielding Ground-Launched Long-Range Missiles

FEBRUARY 2020

At a Glance

The Department of Defense (DoD) has expressed concern that potential adversaries such as Russia and China could prevent the United States from easily gaining air and naval superiority in future conflicts, which could hinder its ability to prosecute military campaigns in certain scenarios in the Baltic region or the South China Sea. The Congressional Budget Office identified several existing weapon systems that DoD could adapt relatively rapidly, at a cost of about $1 billion to $6 billion (in 2020 dollars) for seven batteries, to give U.S. ground forces some limited long-range capabilities in those scenarios:

- **Option 1: A Cruise Missile for Attacking Land Targets.** DoD could procure and field a ground-launched Joint Air-to-Surface Standoff Missile–Extended Range (JASSM-ER). Option 1 has the lowest estimated up-front cost, $1.3 billion, of the four options CBO examined, but the JASSM-ER would have minimal value in either a South China Sea or a Baltic scenario.

- **Option 2: An Antiship Cruise Missile.** DoD could procure and field a ground-launched Long-Range Antiship Missile (LRASM) at an estimated up-front cost of $2.2 billion. The LRASM could be quite valuable in a South China Sea scenario but would have much less value in a Baltic scenario, where Russian naval forces present less of a threat.

- **Option 3: An Air Defense Missile.** DoD could procure and field a ground-launched Standard Missile 6 (SM-6), as well as an air and missile defense radar for each battery, at an estimated up-front cost of $4.6 billion. The SM-6 could have some limited value in a South China Sea scenario, supplementing existing U.S. forces and assisting in defending allies. In a Baltic scenario, the SM-6 could provide significant value, denying Russian forces some advantages.

- **Option 4: A Combination of Antiship and Air Defense Missiles.** DoD could procure and field both a ground-launched LRASM and a ground-launched SM-6 at an estimated up-front cost of $6.3 billion, the most expensive of the four options. Buying both missiles would provide long-range capabilities in both scenarios and would allow DoD to deploy a mix of missiles as appropriate: the LRASM in a South China Sea scenario and the SM-6 in both South China Sea and Baltic scenarios.

Contents

Notes

All years referred to in this report are federal fiscal years, which run from October 1 to September 30 and are designated by the calendar year in which they end.

Costs are expressed in 2020 dollars, adjusted for inflation with the Congressional Budget Office's projection of the gross domestic product price index.

On the cover: A Terminal High Altitude Area Defense interceptor test launch. Photo courtesy of the Department of Defense's Missile Defense Agency.

Summary

In recent conflicts, the U.S. military has focused on rapidly establishing air and naval superiority. During the first Gulf War and operations against Serbia in the 1990s, as well as during operations in Afghanistan and Iraq in the 2000s, the United States and its allies rapidly attained air superiority, which they then used in the fight against hostile forces on the ground.

For future conflicts, however, the Department of Defense (DoD) has expressed concern that potential opponents such as Russia and China could prevent the United States from easily gaining air and naval superiority, which could hinder its ability to prosecute military campaigns.[1] In this report, the Congressional Budget Office examines some of the challenges U.S. forces might face in the current threat environment and the extent to which DoD could mitigate those challenges by procuring and fielding ground-based long-range missiles. Such missiles could counter the advantages that Russia and China have in certain scenarios and would be more difficult for them to suppress than air or naval assets. The missiles could also create some of the same challenges for potential adversaries that U.S. military planners currently face.

CBO identified several existing weapon systems that DoD could adapt to launch from the ground and could procure and field to give U.S. ground forces long-range capabilities: a cruise missile for attacking land targets, an antiship cruise missile, an air defense missile, or a combination of antiship and air defense missiles. By adapting missile systems already or soon to be in the U.S. military's inventory, CBO estimates, DoD could acquire those ground-based capabilities relatively rapidly at an up-front cost of $1 billion to $6 billion, depending on the system. Of course, the Army or the Marine Corps could also develop and build new weapons specifically for those missions, but this report focuses on less costly, short-term solutions that are consistent with DoD's goal of responding quickly to emerging threats.

1. See Department of Defense, *Summary of the 2018 National Defense Strategy of the United States of America* (2018), https://go.usa.gov/xV4SE (PDF, 434 KB).

Using Ground-Launched Long-Range Weapons to Address Potential Threats

Future conflicts with Russia or China could involve scenarios in which the United States and its allies would have difficulty achieving air and naval superiority. For this report, CBO examined two such possibilities:

- A conflict with Russia in the Baltic region, and
- A conflict with China in the South China Sea.

In both types of scenarios, the United States would face a much more technologically adept adversary than it has in recent conflicts. Because both China and Russia would be operating much closer to their own borders than the United States would be, they would have more options for projecting force than the United States would. As a result, either adversary could prevent the United States and its allies from securing air and naval superiority and impede their fight against hostile forces on the ground.

To address such scenarios, the United States could increase its capability to launch conventional missiles from the ground, which it could use to disrupt its opponents' operations even without air and naval superiority. The ground forces launching those missiles would be more difficult for a technologically sophisticated adversary to destroy than air and naval forces, because ground forces are often dug in and dispersed over a wide area. Although U.S. ground forces do not currently operate any of the ground-launched missiles examined in this report, those missiles have all been, or will soon be, fielded by other U.S. military services and would require only modest changes to be launched by ground forces.

Options for Ground-Launched Long-Range Weapons

CBO examined four options that DoD could pursue to provide U.S. ground forces with ground-launched long-range weapons. For each option, CBO assumed that the Army would field seven batteries of missile launchers and purchase 550 missiles of the relevant missile type. The

Summary Table 1.

Ground-Launched Missile Options

	Up-Front Cost (Billions of 2020 dollars)	Annual Cost (Millions of 2020 dollars)	Missile Range (Kilometers)	Intended Target	Value in South China Sea Scenarios	Value in Baltic Scenarios
Option 1: JASSM-ER	1.3	300	925	Static ground targets	Minimal	Minimal
Option 2: LRASM	2.2	300	600[a]	Ships	Significant	Minimal
Option 3: SM-6	4.6	300	240	Aircraft, missiles	Limited	Significant
Option 4: LRASM and SM-6	6.3	300	600[a] and 240	Ships, aircraft, missiles	Significant	Significant

Source: Congressional Budget Office.

JASSM-ER = Joint Air-to-Surface Standoff Missile–Extended Range; LRASM = Long-Range Antiship Missile; SM-6 = Standard Missile 6.

a. The exact range of the LRASM has not been publicly disclosed. For this analysis, CBO used a notional range of 600 km, roughly the midpoint between the publicly disclosed lower bound of the missile (370 km) and the range of the JASSM-ER on which it is based.

batteries would be comparable in size and mobility to the existing seven batteries of the Terminal High Altitude Area Defense (THAAD) missile system. In addition, the Army would need to integrate all the missiles with broader U.S. systems for detecting and engaging targets at long range, and it would need to procure air and missile defense radars for options that include such missiles. The operating costs for all four options would be roughly the same because each would provide for seven batteries of about the same size, but up-front costs to purchase the specific missiles and radars would differ (see Summary Table 1).

Option 1: A Cruise Missile for Attacking Land Targets

In Option 1, DoD would procure and field a ground-launched Joint Air-to-Surface Standoff Missile–Extended Range (JASSM-ER). The Air Force's air-launched JASSM-ER, an extended-range version of its JASSM, is already in production. A cruise missile with low-observable features—making it stealthy and difficult to detect—the JASSM-ER is intended to strike fixed ground targets. A ground-launched JASSM-ER would need a booster motor added to accelerate it to an appropriate speed and altitude.

CBO estimates that this option would have the lowest up-front cost, $1.3 billion (in 2020 dollars), of the four options it examined. In the agency's assessment, however, the ground-launched JASSM-ER would have minimal incremental value in either a South China Sea or a Baltic scenario. Army ground forces could strike valuable land targets with JASSM-ERs in both scenarios, but air-launched JASSM-ERs could also strike those same targets because U.S. aircraft could launch their missiles from outside the range of the adversary's air defenses. Although a ground-launched option might add value as a deterrent or reduce the workload of air-launched missiles, it would only supplement existing capabilities.

Option 2: An Antiship Cruise Missile

In Option 2, DoD would procure and field a ground-launched Long-Range Antiship Missile (LRASM). The Air Force and the Navy already have an air-launched LRASM; it is a variant of the JASSM-ER, but it has a different seeker that allows it to find and strike ships rather than hit fixed ground targets. To make the missile capable of being launched from a ship, the Navy is developing an LRASM variant with a booster motor attached. A ship-launched LRASM could also be launched by ground forces.

Option 2 would have an up-front cost of $2.2 billion, CBO estimates. Ground-launched LRASMs could be quite valuable in a South China Sea scenario, possibly denying Chinese forces the ability to operate surface warships in the area or blockading Chinese commercial shipping. Ground-launched LRASMs would have much less value in a Baltic scenario because Russian naval forces present less of a threat there.

Option 3: An Air Defense Missile

In Option 3, DoD would procure and field a ground-launched Standard Missile 6 (SM-6), as well as an air and missile defense radar for each battery. The SM-6 is a Navy surface-to-air missile that can destroy aircraft, cruise missiles, and ballistic missiles. Designed to be launched from a warship, the SM-6 is already capable of being launched by ground forces.

By CBO's estimate, Option 3 would have an up-front cost of $4.6 billion. Ground-launched SM-6s would not have a long enough range to fully prevent Chinese air forces from operating in the South China Sea, but they could supplement existing U.S. forces and assist in defending allies. Ground-launched SM-6s could, however, deny Russian air forces some advantages in a Baltic scenario.

Option 4: A Combination of Antiship and Air Defense Missiles

In Option 4, DoD would procure and field both a ground-launched LRASM and a ground-launched SM-6. Although Option 4 would be the most expensive option, with an estimated up-front cost of $6.3 billion, buying both missiles would provide long-range capabilities in both scenarios and would allow DoD to deploy a mix of missiles as appropriate: the LRASM in a South China Sea scenario and the SM-6 in both South China Sea and Baltic scenarios.

1

Chapter 1: The Current Threat Environment

The United States has relied heavily on its air and sea forces in conflicts since World War II, and its ground forces have almost always possessed air superiority. That superiority comes both from the Air Force and from U.S. naval forces, which include aircraft carriers and their associated air wings and battle groups and, in more modern times, cruise missiles fired from submarines and surface combatants.

Currently, the most demanding planning scenarios envisioned by the Department of Defense involve conflicts with Russia and China. Both countries have invested heavily in weapon systems that could prevent the United States from freely using its potent air and naval forces in areas near their borders. Those weapons, collectively referred to as antiaccess and area-denial (A2/AD) systems, aim to nullify the strengths of the United States in the air and at sea and exploit its dependence on those domains to project power.

If U.S. ground forces had new long-range weapon systems, they would be more capable of operating without air and naval support in hostile threat environments against Russia and China and could also assist U.S. air and naval forces. Those weapons might also allow U.S. ground forces to challenge Russian and Chinese A2/AD systems and deny them their objectives, even in the absence of U.S. air and naval superiority. Such capabilities could reduce the effectiveness of attacks on U.S. air and naval forces, help counter enemy strategies, and bolster deterrence in both regions.

Currently, the U.S. military's ground-launched missile capabilities are limited, in both the type and the range of the weapon systems used. In this report, the Congressional Budget Office examines several near-term options for expanding those capabilities with longer-range missiles, which would give U.S. ground forces more opportunities to contribute in the scenarios that DoD envisions.

A2/AD Strategies and Asymmetric Warfare

The United States relies on the strength of its air and naval platforms, which have sophisticated munitions designed to devastate opponents' air and naval forces and then conduct strikes and support U.S. ground forces. A2/AD strategies against the United States rely on long-range air defense and antiship missiles to reduce its advantage in those areas, rendering it less able to establish air and naval superiority and to support U.S. ground forces or strike key targets. Such strategies are a form of what is known as asymmetric warfare.[1] For the past two decades, that term has been most commonly used to describe insurgencies carried out through guerrilla warfare.[2] In a broader sense, however, the term refers to warfare conducted in ways that prevent an opponent from capitalizing on its particular strengths—such as when a U.S. adversary favors guerrilla action over open battle.

Asymmetric strategies are intended to be difficult for existing U.S. forces to counter, making "more of the same" responses less effective. For example, although a larger Navy would be more capable of dealing with antiship missile threats, deploying a larger force would be a relatively ineffective response compared with responses that would be less vulnerable to those antiship missiles. Responses that exploit an opponent's vulnerabilities are generally preferable. For example, U.S. antiship missiles would be a relatively effective response against Chinese antiship missiles intended to deny U.S. ships the ability to contest the South China Sea and prevent Chinese ships from operating there.

Although the United States often describes the combat methods of opponents and potential opponents as asymmetric warfare, from an external perspective it practices

1. In particular, the United States has concentrated much of its ability to project power in aircraft carriers and their battle groups. U.S. defense planners have long been concerned about the vulnerability of aircraft carriers to attack, which could be a key factor in any hypothetical conflict.

2. See the RAND Corporation's research on asymmetric warfare at www.rand.org/topics/asymmetric-warfare.html.

asymmetric warfare as well. It has invested heavily in air and naval forces because it prefers to use its economic and technological strength against hostile ground forces rather than engage in large-scale, protracted battles of attrition against opponents with relatively large numbers of troops and recruits (such as Japan or Germany during World War II, China during the Korean War, North Vietnam during the Vietnam War, or the Soviet Union in any potential conflict in central Europe during the Cold War). In more recent decades, the United States has routinely capitalized on its ability to freely use cruise missile strikes, air strikes, and remotely piloted aerial vehicle strikes against opponents with limited or no air defenses.

Much like guerrilla warfare, A2/AD strategies are intended to be difficult for existing U.S. systems to counter. A2/AD strategies that pose significant challenges to U.S. forces involve long-range surface-to-air missiles, long-range antiship missiles, land-attack cruise missiles, ballistic missiles, and those missiles' sensor and command and control systems. Especially when combined, long-range air defense and antiship systems can prevent U.S. forces from accessing a theater (that is, from accessing the ports, air bases, and other infrastructure they need to project power) and from using broad areas of the theater for military operations (area denial).

Long-Range Surface-to-Air Missile Systems (SAMs)

Russia has widely exported its latest air defense systems, the S-300/400 family; China's major systems are largely domestic versions of the same technology. Both systems combine multiple types of advanced radars with multiple types of long-range SAMs, all mounted on mobile platforms, and some integrate shorter-range (point-defense) systems as well. Russia's longest-range missiles purportedly can reach 400 kilometers (km), or roughly 250 miles, although those missiles have not been produced, fielded, or exported as widely as missiles with ranges between 150 km (95 miles) and 200 km (125 miles).

Traditionally, the tactics the United States uses to suppress enemy air defenses (SEAD missions) combine two types of weapons carried by aircraft. Extended-range antiradiation missiles (ARMs) lock onto signals from air defense radars and attempt to destroy them. Shorter-range direct-attack weapons are usually cluster munitions that disperse many smaller bomblets over an area to destroy soft targets (targets that are not protected or armored and therefore are easy to destroy with small munitions).

Aircraft engaged in SEAD missions approach hostile air defenses at low altitude, using ground terrain to avoid being detected by radar, and then fire their ARMs at hostile radars from an extended range. Defenders must choose whether to continue to use their radars—and risk having them destroyed by the ARMs—or to power them down, leaving the air defense system unable to find and engage targets. Powering down also leaves the air defenses in a vulnerable position because attacking aircraft know the location of the radars and can use direct-attack weapons to strike them, as well as any missile launchers or command and control sites they can locate, with relatively low risk of retaliation.

The United States has developed significant expertise in SEAD tactics since the Vietnam War and has repeatedly improved the technical systems needed to use them successfully (including ARMs, extended-range cluster munitions, advanced sensors to detect hostile radars, and low-observable aircraft). Many of those successes, however, have been against opponents with older and less advanced air defense technologies, such as Iraq and Libya. Against a more sophisticated opponent, such as Serbia during the North Atlantic Treaty Organization's (NATO's) Operation Allied Force in 1999, the U.S.-led air campaign suppressed but never completely destroyed the air defenses.

Since the Soviet era, Russian forces have treated air defense as a critical need and have focused their designs on deflecting U.S. attacks. The long range of Russian SAMs allows their A2/AD systems to threaten SEAD aircraft before they are close enough to their targets to fire their ARMs. Because the SAMs are mobile, they can disperse and change positions, making a direct attack more difficult, particularly from long-range weapons with lengthy flight times. In addition, point-defense systems capable of shooting down incoming munitions may blunt the effects of ARMs or standoff cluster munition attacks.[3]

Russian air defenses include a variety of radars operating in different frequency ranges, making low-observable aircraft easier to detect. Suppressing such a system would

3. Standoff weapons are missiles or bombs that are launched at a distance sufficient to allow attacking personnel to evade defensive fire from the target area.

involve more risk, difficulty, and time than SEAD campaigns the United States has previously undertaken. At the same time, the long range of those systems could threaten U.S. air operations across much of any potential theater, especially if the conflict included enemy fighter aircraft, attacks on U.S. air bases in the theater, and potential attacks on U.S. aerial refueling tankers operating close to defended airspace, all of which could prevent U.S. aircraft from engaging freely in many types of missions.

Air warfare has a relatively straightforward attrition logic: If it is sustained for long enough, almost any level of aircraft loss can render air forces incapable of combat. Modern aircraft cannot be replaced fast enough for replacement to be relevant in the potential high-end conflicts with Russia or China envisioned today, and the level of attrition that makes air forces incapable of combat is low enough that effective use of air forces requires complete or near complete air superiority. In other words, modern air forces cannot operate for any extended period of time in the face of effective defenses.[4] For that reason, even if ground-based air defenses do not successfully shoot down many aircraft, they can seriously complicate and protract air operations by forcing SEAD missions to continue for extended periods of time, tying up many aircraft that could otherwise be used for other missions.[5]

Long-Range Antiship Missiles (ASMs)

Most modern ASMs are cruise missiles—that is, they have internal jet engines and fuel supplies; they fly horizontally, much like conventional airplanes; they can be launched from a variety of platforms; and their ranges can extend to several hundred kilometers. Traditional cruise missiles fly at subsonic speeds and typically carry their own radar seekers to detect ships. More modern cruise missiles fly at supersonic speeds and can accept targeting information from other platforms but still have their own seekers. An advanced Chinese weapon system that has captured much attention, the DF-21, may combine a ballistic missile's speed, range, and ability to penetrate defenses with the ability to target ships. The DF-21D is credited with a range of about 1,500 km (930 miles) and a flight time of about 10 minutes.

There has been relatively little actual combat with ASMs, so it is not well understood how modern naval combat with large numbers of warships and cruise missiles would occur in any hypothetical scenario (although the United States was deeply concerned about Soviet ASMs during the Cold War). There is, however, a rough but generally accepted theoretical framework for how ASM attacks on naval platforms would play out.

ASMs can acquire, hit, and destroy naval vessels if they have useful targeting information; even a single ASM hit can inflict enormous damage. Although few nations possess many warships—the U.S. fleet is the largest with about 300—ASMs are comparatively cheap and can be purchased and fielded in much larger numbers. Defenses against ASMs can and do fail, and naval vessels engaged in combat with them face both "leakage" and "saturation." Leakage occurs when many ASMs are fired against imperfect defenses, because it is always possible for at least one ASM to penetrate those defenses and cause damage. Saturation refers to the finite capacity of even a perfect defense system to engage incoming ASMs, because it is possible to fire more ASMs than that system can engage. Thus, although the effectiveness of modern ASMs against modern warships is not known, the mere presence of many ASMs and an effective targeting system would probably preclude surface warships from operating in a theater within range of those ASMs.

In planning to counter ASMs, the United States has focused on attacking their targeting systems. However, Russia and China have fielded a range of sensors that can acquire targets, including airborne systems, long-range and over-the-horizon radars, and satellite-based sensors, making it more complicated for the United States to target them. Suppressing satellite-based sensors would be difficult because the United States has signed treaties

4. The most common way to think of attrition logic is to posit aircraft as having risk *p* per unit of time of being destroyed. The fraction of the force that will remain combat effective at some future point in time is then modeled as (1-*p*)^units of time. The compounding nature of this attrition is dramatic because modern aircraft may easily fly two combat sorties per day. If they face a 1 percent risk of loss on each sortie, two-thirds of the force would be lost within three weeks. Such logic—that even a 1 percent risk of loss on each sortie is unsustainable—dictates that modern air forces, which typically have a relatively small number of technically sophisticated aircraft, cannot operate in the face of meaningful air defenses for any extended time.

5. For a discussion of the challenges associated with conducting a broader air campaign while also conducting a SEAD campaign, see Daniel Baltrusaitis, "Quest for the High Ground: The Development of SEAD Strategy" (thesis, School of Advanced Airpower Studies, Maxwell Air Force Base, 1997), https://go.usa.gov/xygQ4 (PDF, 458 KB).

banning the use of weapons in space, and it depends on satellites to such a degree that attacking an adversary's assets in space could have many disadvantages. In addition, ground-launched ASMs may not emit easily detectable sensor signals because they rely on external targeting systems rather than their own sensors; they can also be mounted on trucks to take advantage of terrain and camouflage. In naval scenarios such as a potential conflict in the South China Sea, the credible threat of ASM attack could prevent U.S. surface warships and carrier strike groups from accessing the theater.

Land-Attack Cruise Missiles (LACMs) and Ballistic Missiles

Modern land-attack missiles like the ones that Russia and China have fielded can be either cruise or ballistic missiles launched from a variety of platforms.[6] Each has its own technical advantages. In general, such missiles are difficult, but not impossible, to defend against and are best suited to attacking a relatively small number of high-value, immobile land targets.[7] LACMs are typically not considered a major threat to ground forces in the field because those forces are mobile and usually highly dispersed, and attacking them effectively would require far more missiles than any potential opponent could afford. LACMs can effectively attack critical infrastructure, however, such as air bases, supply depots, or command and control sites, and they can attack civilian targets—a tactic some analysts believe China might use in a conflict over Taiwan.

In some scenarios, effective use of land-attack missiles could significantly impair the U.S. military's operations. In the Pacific, the United States relies on a relatively small number of air bases that lack thick concrete aircraft hangars and secure storage areas for fuel and weapons. A large-scale Chinese ballistic missile attack on those air bases could destroy U.S. aircraft on the ground, and repeated attacks over the course of a conflict could curtail or disrupt U.S. operations from those bases. Similarly, in a high-end ground conflict with Russian forces in the Baltics, U.S. ground forces would require massive logistical support involving large fuel, supply, and ammunition depots and accessible ports for their delivery. Attacks on logistics sites could severely degrade the ability of U.S. ground forces to sustain effective combat operations.

Like ASM defenses, effective LACM defenses cannot escape the problems of leakage and saturation. Unlike leakage of ASMs, however, the leakage of a few conventionally armed land-attack missiles does not usually cause massive damage. A single ASM can destroy a warship, but a single LACM is unlikely to neutralize a ground target. The United States often uses dozens of cruise missiles to attack a single site; the 2017 strike on Syria's Shayrat Airbase, for example, involved about 60 Tomahawk cruise missiles. Ground targets are typically more dispersed than warships, and they are more resilient: It is easier to fight fires on land, sinking is not a danger, and concrete is inexpensive and can absorb explosive blasts effectively. As a result, LACMs cannot prevent U.S. ground forces from operating in a theater in the same way that SAMs or ASMs can prevent U.S. air or naval forces from doing so. In both Operation Desert Storm and Operation Iraqi Freedom, U.S. ground forces operated in theaters under active ballistic missile threats.

Enabling and Supporting Systems

Long-range weapons like SAMs, ASMs, and LACMs require extensive support from sensors to detect and track targets and from communications and command infrastructure to provide information about those targets to decisionmakers and weapon platforms. The U.S. military often describes all the steps involved in effectively using a weapon—from searching for targets to assessing battle damage after an attack—as a kill chain (see Box 1-1).

Although some types of antiaccess weapons combine sensors, command and control, and weapons into a single platform or relatively compact unit (such as a ship with its own radar, commander, and missile battery), such systems often use distributed sensors and weapon platforms to achieve maximum effects. For example, although the most modern Russian SAMs have their own radars to detect and track targets, they rely on additional

6. Ballistic missiles are named for their ballistic trajectory; rocket motors propel them up along a predictable, parabolic path, and gravity brings them back down.

7. Although such missiles can carry nuclear warheads, this study focuses on nonnuclear missiles. The use of nuclear weapons would vastly complicate the scenarios examined in this report because they would signal a significant escalation in a conflict. That latent nuclear threat exists in any conflict with Russia or China, but the point at which U.S. actions would lead to the use of nuclear weapons is unknown.

sensors—such as aircraft with airborne early warning radars—to extend their range.[8]

Both Russia and China have extensive networks of sensors, including radar satellites, imaging satellites, airborne early warning aircraft, and air defense radar networks, that help them use their weapon systems effectively. With less technologically advanced opponents, the United States has often attempted to destroy the sensors that supply information to A2/AD weapon systems, thus reducing their utility. With more advanced opponents whose sensors are more sophisticated, however, such operations are less likely to be fully successful.

Scenarios That Concern U.S. Defense Planners

Two types of scenarios are of particular interest in planning the U.S. military's defense against A2/AD systems: those involving the Baltic region and the South China Sea.

Baltic Scenarios

In Baltic scenarios, it is assumed that Russia attacks one or more of the Baltic states (Estonia, Latvia, and Lithuania). Although many versions of such a conflict are possible, they can be broadly divided into fast scenarios, in which Russian military forces cross the border and make a rapid push to seize and hold terrain, and slow scenarios, in which Russian aggression is less overt—through the use of local proxy forces, or "little green men," as in the conflict with Ukraine.[9]

In fast scenarios, Russian forces would use their proximity to the Baltic capital cities, access to Belarussian territory, and the very limited presence of NATO forces to quickly overrun the Baltic states. NATO would either have to accept Russian aggression as successful and establish a new status quo or mount a counterattack to liberate the Baltic states from Russian forces.

A variety of factors, including the geography of the Baltic theater and the types of Russian forces present there, would make it difficult for NATO to defend, or counterattack into, the Baltic states:

- The small size of the Baltic states, their proximity to Russia, the Kaliningrad exclave (the noncontiguous portion of Russian territory on the Baltic between Lithuania and Poland), and Belarussian alignment with Russia make the Baltic states easily accessible to Russian ground forces but not to other NATO states (see Figure 1-1 on page 12). Russia could fire long-range land-attack missiles at almost any NATO target of interest in the theater.

- Attempting to use NATO's naval assets in the Baltic Sea would be very risky. Russia has significant ASM capabilities, and the Baltic Sea is relatively small and enclosed, offering NATO's naval forces limited ability to maneuver away from that ASM threat.

- The Baltic states do not have large military forces, and no major NATO forces are permanently stationed there. The United States has recently been rotating battalion-sized units into the Baltics as a deterrent, but those forces could not halt a major Russian ground offensive.

- Russian air defenses, including those in the Kaliningrad enclave and outside Saint Petersburg, cover the entire theater, and the Kaliningrad defenses could threaten much of Poland's airspace as well (Figure 1-1 on page 12). Using NATO's airpower in support of its ground forces would be dangerous until NATO forces could conduct a successful SEAD campaign against Russian air defenses. But such a campaign would probably require strikes on Russian territory, which Russia could view as highly escalatory.

- Russian and Soviet forces have traditionally used heavy but less accurate artillery fires to damage

8. Radar, like visible light, has a horizon below which it cannot detect targets. Because of the curvature of the earth, at long ranges this horizon increasingly restricts radar's ability to detect targets below a certain altitude, and that altitude increases with distance. Airborne radars, because of their high elevation, have a much lower horizon than ground-level radars. NATO describes the range of its airborne warning and control system (AWACS) aircraft radars against low-flying targets as 400 km (250 miles) from normal cruising altitude, a value that agrees with calculated values. See North Atlantic Treaty Organization, "NATO AWACS Surveillance Aircraft Support to the Counter ISIL Coalition" (fact sheet, February 2017), https://tinyurl.com/yxdx26hj. For comparison, a ground radar would typically be able to detect low-flying targets from no more than 40 km to 50 km (25 miles to 30 miles) away.

9. The term "little green men" has become a shorthand reference for a purported style of Russian infiltration and destabilization of its neighbors through plausibly deniable means. See U.S. Army Special Operations Command, "*Little Green Men*"*: A Primer on Modern Russian Unconventional Warfare, Ukraine 2013–2014* (2016), https://tinyurl.com/y2wdcvjo (PDF, 8.78 MB).

Box 1-1.

The Kill Chain

In modern military operations, the kill chain refers to the full sequence of actions between finding targets and confirming their destruction. The term can describe many types of engagement, including some civilian ones. The overarching idea is that using any weapon system effectively involves identifying targets, determining their precise location, deciding to engage them with a particular weapon, gathering information from internal and external sensors before attacking, using the weapon system, and assessing the effects after its use.

In the context of relatively simple engagements, such as an infantry firefight, the steps in the kill chain may happen very rapidly, with little coordination between different parts of the force. For example, an infantryman sees possible enemy combatants, observes their location and behavior, and uses suppressive rifle fire while alerting the squad leader. With long-range weapons such as antiaccess and area-denial (A2/AD) systems, however, the entire kill chain may require different systems to perform several complex steps in coordination.

Crucially, interfering with an attacker at any step along the kill chain can impede its ability to effectively use its weapons. The farther away the target, the more effective such interference can be. For example, an attack on a hostile ship might rely on radar satellites to alert military commanders to the presence of a hostile ship as a potential target. Aircraft with radar would confirm the ship's location and identity and track it as commanders decide whether to launch antiship missiles from ground launchers within range of the location the aircraft provided. If so, the missiles would be launched and fly to their targets, and commanders would use sensors to determine if they achieved the desired effect or if a subsequent engagement, such as a second attack, was necessary. If that ship had not been detected in the first place, if its position could not be confirmed or it could not be tracked, if commanders could not agree to engage it, if they lacked suitable weapons, or if the attack left the commanders unaware that subsequent engagement would be needed, the ship would survive.

In general, U.S. military doctrine prefers to disrupt attacks against U.S. forces as early in the kill chain as possible. U.S. warships, for example, have point-defense guns intended to shoot down incoming antiship missiles, but those are viewed as last-resort weapons. Instead, the Navy prefers to operate its ships so that they are as difficult to detect and target as possible—for example, by remaining far from potential threats, curtailing the use of communication systems or active sensors like radars that would reveal their position, striking with long-range weapons and aircraft, and using submarines.

One influential idea among many U.S. military professionals is that the best way to blunt the effect of hostile A2/AD systems is to aggressively attack the entire kill chain that enables the use of those systems. In that view, although it would be almost impossible to destroy all hostile antiship missile ground launchers, such an action would be unnecessary and pointless as long as all the sensors that fed them useful targeting information could be attacked. Such sensors might also be fewer in number and easier to target, and having had "their eyes shot out," the remaining missiles would present a minimal threat to U.S. forces.[1] The United States has achieved success with this approach—for example, with the suppression of enemy air defenses (SEAD) campaign in Operation Desert Storm, which

1. For an exposition of this point of view that describes a plan of operations with an explicit blinding campaign against opposing sensors and networks, see Jan van Tol and others, *AirSea Battle: A Point-of-Departure Operational Concept* (Center for Strategic and Budgetary Assessments, 2010), https://tinyurl.com/y3v9np4q (PDF, 4.59 MB).

Continued

opposing ground forces. In the conflict with Ukraine, however, Russian forces used remotely piloted aerial vehicles and other intelligence, surveillance, and reconnaissance assets to direct their artillery much more precisely, causing extensive damage to the Ukrainian forces. In a Baltic conflict, NATO ground forces would probably also incur significant casualties unless NATO forces could prevent Russia from using those assets and present their own robust counterbattery capability.[10]

A fast scenario—in which Russian forces rapidly seize the Baltic states and NATO mounts a counterattack to liberate them—thus poses many military challenges. Russia's long-range air defenses and ASMs would greatly inhibit the ability of NATO's air or naval forces to assist in the campaign. NATO's air forces would be required to first begin a challenging SEAD campaign (which might

10. Counterbattery fire refers to the use of artillery systems to attack an opponent's artillery systems. U.S. artillery is equipped with specialized radars that can detect artillery projectiles in midair, calculate the position those shells originated from, and transmit that information to artillery firing batteries, which would typically respond by quickly firing rockets at those firing positions.

Box 1-1. Continued

The Kill Chain

prioritized air defense radars and command sites rather than surface-to-air missile launcher sites.

Other U.S. military professionals warn that kill-chain disruption may not be feasible against a large, competent opponent such as Russia or China.[2] Both of those potential opponents, for example, may have radar satellites capable of locating naval targets in the near future.[3] Attacking those satellites could be viewed as highly escalatory and could expand a conflict into space, where the United States also has many assets that are potentially vulnerable to attack.[4] Similarly, attacking command sites within Russia or China could be considered highly escalatory; moreover, large and competent opponents typically have more robust command structures with more redundancy.

Although the United States has invested in robust sensors and communications links that allow U.S. forces to gather much information about theaters of operations and effectively use a wide range of weapons against them, the long-range missile options considered in this report would all require some additional elements to fully enable their own kill chains:

- Air and missile defense weapons would need their own radars, capable of acquiring and tracking targets. Even when those systems were expected to engage targets beyond the range or horizon of their own radars, an organic ability to detect targets would be useful for self-defense as well as to minimize the burden placed on other assets.
- All long-range weapon systems would require integration with the larger sensor networks that the United States employs. For example, in a South China Sea scenario, long-range ground-launched weapons would need to be able to accept targeting information from Navy aircraft. Fortunately, many of those systems already exist today. The Navy has a communications network through which one Navy aircraft, such as an E-2D Hawkeye, can direct the fire of other Navy aircraft or ships. In addition, those sensors and networks would need to be in appropriate locations for long-range ground-based systems to be effective.

2. In recent years, U.S. planners have debated about air-sea battles, associated with kill-chain disruption, versus multidomain battles, the idea that against near-peer competitors the United States will need to defeat enemies in multiple domains and will not be able to rely on a blinding campaign. See, for example, the discussion of defeating enemies in armed conflict in U.S. Army Training and Doctrine Command, *Multi-Domain Battle: Evolution of Combined Arms for the 21st Century* (2017), section 3-5, https://go.usa.gov/xyPzN (PDF, 2.23 MB).

3. The purpose and status of some current Chinese and Russian satellites are unclear. China has radar satellites with ostensibly civilian missions currently in orbit. Russia does not, but it has developed and launched several series of radar satellites in the past and is developing another series.

4. There has also been speculation about the vulnerability of the United States to a potential surprise attack on its space and cyber assets (sometimes called Space Pearl Harbor or Cyber Pearl Harbor), which could affect its kill chain and which it might view as highly escalatory.

require striking targets on Russian territory) against one of the most sophisticated hostile air defense systems in the world. NATO's ground forces would be required to begin a ground campaign with their logistical and command and control nodes threatened by Russian land-attack missiles, without the benefit of full command of the air. In some cases, NATO's ground forces might themselves be exposed to Russian air attack or powerful Russian artillery strikes.

But Russia would also face significant difficulties. If NATO chose to strike targets in Russia with cruise missiles, for example, Russian forces would need to defend a very large territory against those strikes. If NATO forces established air superiority, its ground forces would probably prevail over Russian ground forces in direct combat. And although Russia has long invested heavily in artillery systems, the United States has long invested heavily in counterbattery systems. According to some reports, Russia perceives the possibility of NATO cruise missile attacks or land invasions as sufficiently worrisome to consider using nuclear weapons to deter them.[11]

11. See Scott Boston and Dara Massicot, *The Russian Way of Warfare: A Primer* (RAND Corporation, 2017), www.rand.org/pubs/perspectives/PE231.html; and Thomas R. McCabe, "The Russian Perception of the NATO Aerospace Threat," *Air and Space Power Journal*, vol. 30, no. 3 (Fall 2016), https://tinyurl.com/y2q49aa8 (PDF, 206 KB). The possible use of nuclear weapons makes any conflict between any two nuclear-capable countries highly risky and dangerous, although most nuclear countries have official policies and doctrines forswearing the use of nuclear weapons for conventional warfare. It is unclear how true that is for current Russian nuclear policy, particularly if Russian territory was under attack. The same risks exist with China in a South China Sea scenario. The presence of nuclear weapons makes conflicts like the ones in the scenarios that CBO examined complex, even if nuclear weapons are never used or brandished. For that reason, some analysts argue that large-scale conventional conflicts like the ones in DoD's scenarios are unlikely.

Figure 1-1.

Approximate Range of Russian Air Defenses in the Baltic Region

Source: Congressional Budget Office.

South China Sea Scenarios

In South China Sea scenarios, it is usually assumed that China attempts to use its possession of disputed islands (in particular, the Paracel and Spratly Islands, as well as Scarborough Shoal) in the South China Sea to exert control over neighboring states that are allied with the United States. In such an event, either China or the United States could initiate armed conflict. Some observers have suggested that China could initiate a strong surprise attack to cripple U.S. military bases in the western Pacific with ballistic and cruise missiles; conflict could also arise if a country such as the Philippines or Vietnam asked the United States for aid during a crisis with China.[12] Conflicts over control of the South China Sea would most likely involve control of the disputed islands

12. See Sam Goldsmith, "U.S. Conventional Access Strategy: Denying China a Conventional First-Strike Capability," *Naval War College Review*, vol. 72, no. 2 (Spring 2019), https://tinyurl.com/y3ndkv38; and David C. Gompert, Astrid Stuth Cevallos, and Cristina L. Garafola, *War With China: Thinking Through the Unthinkable* (RAND Corporation, 2016), www.rand.org/pubs/research_reports/RR1140.html.

in the region, as well as the degree to which U.S. and Chinese forces could prevent each other from operating effectively within the theater.

A combination of many factors, including the geography of the South China Sea theater and the types of Chinese forces located there, would make any conflict in the region challenging for the United States:

- China currently exercises de facto control over several of the disputed islands and has been rapidly converting them into military outposts capable of projecting power throughout the theater, which is relatively close to the Chinese mainland.

- The so-called first island chain, stretching from Japan to Taiwan, the Philippines, and the Indonesian archipelago, could allow countries surrounding the South and East China Seas to isolate China from maritime access to the rest of the world (see Figure 1-2). Although much of the island chain is composed of countries allied with the United States, U.S. military presence in the region is modest and mostly concentrated around the East China Sea in the north.

- China has spent decades investing heavily in its navy, as well as in cruise and ballistic missiles. Chinese forces on the mainland could credibly attack U.S. air bases anywhere in the region with ballistic missiles and could threaten naval forces within much of the theater.

- The Chinese have domestic versions of modern air defense systems similar to the Russian S-300 series and have purchased Russian S-400 series air defense systems. Efforts to use U.S. airpower in support of U.S. naval operations would be quite dangerous until U.S. forces successfully suppressed Chinese air defenses.

- With ASMs and air defenses located on the militarized islands, China could deny U.S. air and naval forces access to almost the entire South China Sea (see Figure 1-2).

- U.S. forces would have limited ability to destroy or seriously degrade China's power projection over the South China Sea without striking the Chinese mainland directly, which China could view as highly escalatory.

- There is no feasible scenario in which the United States could use its ground forces to invade the Chinese mainland to accomplish its objectives in such a conflict.

The United States would thus have few options to prevent China from asserting control over the South China Sea, other than to seize the disputed islands and attempt to destroy enough Chinese air and naval forces that China would accept the new status quo. Such an attempt would be highly risky for U.S. forces because it would have to be undertaken by U.S. air and naval forces that would be highly vulnerable to Chinese A2/AD systems in the theater. The sheer number of Chinese ASMs, as well as the difficulty involved in destroying ground-launched ASMs, would probably make it impossible for U.S. naval forces to operate freely in the western half of the South China Sea.

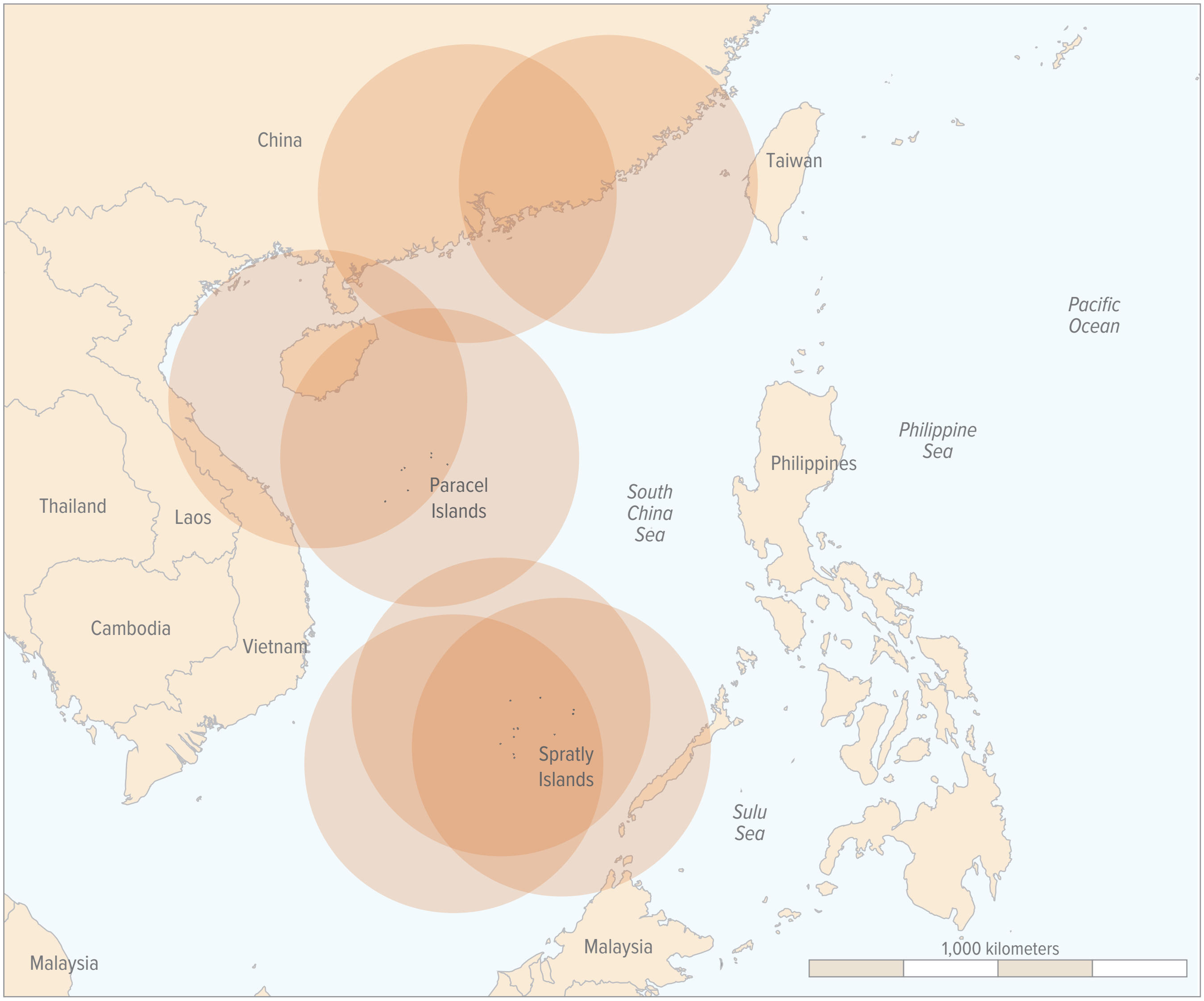
At the same time, however, China would have limited ability to project power beyond the first island chain. One possible outcome of a conflict in the South China Sea is mutual denial, in which the United States and China each prevent the other from operating freely. Alternatively, because any South China Sea scenario would almost certainly involve other countries in the region (such as Japan, Taiwan, the Philippines, Vietnam, or Singapore), another possible outcome might hinge on China's ability to coerce those countries to concede their claims to disputed islands, refuse to cooperate with the United States, or in some other way accede to Chinese regional dominance.

Existing Capabilities of U.S. Forces

Russia and China both have substantial A2/AD capabilities based on ground-launched platforms intended to counter the advantage the United States has in its air and naval platforms. Ground-launched platforms are intrinsically cheaper than air or naval platforms, and both countries are capable of projecting power in the relevant scenarios from their own territory—unlike the United States, which would have to deploy its forces by air and sea to foreign territory. Ground forces are also intrinsically resilient in a way that air and naval forces are not, because they are more difficult to destroy with air or naval attacks (see Box 1-2).

Figure 1-2.

Approximate Coverage Areas of Potential Chinese Air Defenses in the South China Sea If Deployed on Militarized Islands



Source: Congressional Budget Office.

By contrast, the United States has concentrated its antiair, antiship, and long-range land-attack capabilities on air and naval platforms, often paying a premium for platforms that can project power far from home. Establishing air and naval superiority is typically considered a prerequisite for gaining access to a theater, and U.S. air and naval assets have long been capable of providing powerful support to U.S. ground forces engaged with opposing ground forces. In a theater in which the air and sea domains are contested, however, an opponent might be able to use A2/AD systems to deny the United States access to those domains, but the United States might not be able to deny its opponent access to them.

The converse of the United States' preference for concentrating those antiair, antiship, and long-range land-attack capabilities on air and naval platforms is that its ground forces have fairly minimal capability in each respect. U.S. ground forces have no dedicated antiship capability at all, and their antiair and land-attack capabilities have a relatively short range compared with those of the Russian and Chinese forces. U.S. ground forces would be largely

Box 1-2.

The Resilience of Ground Forces

Compared with land warfare, air and naval warfare typically concentrate many military capabilities into a relatively small number of high-cost platforms, operating in a relatively simple environment—that is, an environment in which terrain and civilians play a relatively limited role. Those characteristics make air and naval forces easier to target than ground forces, and they can be destroyed by striking far fewer aim points. A single successful attack can destroy a major weapon platform that represents a significant amount of military power. By contrast, ground forces are more resilient against attacks by high-end conventional weapons such as cruise or ballistic missiles.

Even a fairly small ground combat unit, such as an Army brigade combat team, can easily include more units and platforms than all the air and naval platforms present in a theater combined. An armored brigade combat team, for example, includes about 300 armored vehicles and 600 wheeled vehicles. In most operations, the sheer number of separate ground combat units allows them to be dispersed over large areas of terrain. Dispersion helps protect ground combat units from the firepower of modern weaponry; it is, in most cases, impossible to destroy a major ground combat unit with a single attack. Moreover, because cruise and ballistic missiles are relatively expensive, attempts to destroy ground forces in the field with such weapons can be prohibitively costly.

In addition to being dispersed, competent ground forces engaged in land warfare can use features of the terrain, as well as camouflage, decoys, and other measures, to conceal their location and increase their chances of survival. Almost all ground forces use terrain to resist attack, either by seeking cover behind it or entrenching themselves within it. The more complex the terrain, the more opportunities defending ground forces typically have to use it to their advantage. During World War II, for example, Japanese forces occupying some islands in the Pacific were able to survive extended air and naval bombardments; urban areas provide similar advantages. Even fixed ground installations, such as those protected by reinforced concrete, can often absorb explosive blasts.

Two recent U.S. combat operations illustrate the challenges of attacking ground units. During Operation Desert Storm, the United States sent hundreds of aircraft over several weeks to locate and destroy a relatively small number of Iraqi Scud missile launchers in a barren desert environment. When the hostilities ended, the United States could not confirm that it had destroyed any mobile Scud launchers.[1] During Operation Allied Force, the North Atlantic Treaty Organization's bombing campaign against Yugoslavia, U.S. and allied forces could not significantly degrade the Yugoslavian air defense system. Although they suppressed the Yugoslavian air defenses, they could not destroy most of them and could not operate freely for the duration of the conflict. In both situations, the United States had significant advantages in technology and airpower, but the relatively small enemy ground forces were able to avoid destruction and continue to operate, although less effectively.

Because of such considerations, U.S. military planners do not generally believe that an adversary's ground-launched antiaccess and area-denial (A2/AD) systems can be reliably or quickly suppressed or destroyed; indeed, those systems would not be a concern if they were vulnerable. Because air attacks are unlikely to eliminate ground-launched antiship missiles (ASMs), no feasible means currently exist to ensure, for example, the complete destruction of truck-mounted ASMs in a theater that has many of those defenses. Such a threat requires either ground forces to seize the territory where the ASMs are located or a separate campaign to destroy the sensors that provide them with information about distant targets. Antiair defenses, however, remain a partial exception to this principle. As Operation Allied Force demonstrated, modern air campaigns can reliably suppress competent and mobile hostile air defense systems—for example, by forcing them to turn their radars off and remain concealed—but it is difficult to destroy them completely.

If the United States adopted A2/AD systems for its own use, it could obtain similar benefits. Although existing U.S. air and naval platforms that can fire ASMs might be highly vulnerable to enemy A2/AD systems, new ground-launched systems would have the same advantages against missile attack that hostile A2/AD systems do. By deploying ground-launched long-range missile capabilities, the United States could pose the same challenges for its potential adversaries that U.S. military planners currently face.

1. DoD's retrospective on Operation Desert Storm states, "Once again, there is no indisputable proof that Scud mobile launchers—as opposed to high-fidelity decoys, trucks, or other objects with Scud-like signatures—were destroyed by fixed-wing aircraft." See Thomas A. Keaney and Eliot A. Cohen, *Gulf War Air Power Survey Summary Report* (Department of Defense, Defense Technical Information Center, 1993), pp. 89–90, https://apps.dtic.mil/dtic/tr/fulltext/u2/a273996.pdf (14.1 MB).

unable to support U.S. air and naval forces in any contest for control of the air or sea.

The Army, in particular, has recognized the limitations of its forces in these possible scenarios and has begun programs to enhance its antiair, antiship, and long-range land-attack capabilities.

Antiair

The Army's existing air defense systems are divided between short-range air defense (SHORAD) systems and high- and medium-range air defense (HIMAD) systems. The SHORAD systems are mostly based on the Stinger missile, which has a fairly limited capability.[13] The Army has launched several initiatives to improve its SHORAD capability. The Marine Corps currently operates the same Stinger missile-based systems that the Army does and also has tactical aircraft for directly engaging opposing aircraft.

The Army's HIMAD systems include the Patriot and the Terminal High Altitude Area Defense. The THAAD system is intended exclusively for ballistic missile defense, whereas the Patriot system was originally developed for medium-range air defense, but its most recent variants have been largely intended for ballistic missile defense. The Army has not pursued new long-range air defense capabilities in this area as actively as it has with SHORAD.

Antiship

Historically, the Army has not had any dedicated antiship systems since it disbanded the coastal artillery after World War II. Although cannon and rocket artillery can attack ships, their effectiveness and range would be limited without the addition of specialized sensors and guidance systems. Army and Marine Corps helicopters can attack unarmed ships, and the Marine Corps has tactical aircraft capable of performing this role as well.

The Army is upgrading some of its Army Tactical Missile System (ATACMS) missiles, the longest-range ballistic missiles in its current inventory, into an antiship variant. The ATACMS missile is no longer in production, however, and the Army plans to develop a new Precision Strike Missile that will have an antiship variant when it is eventually fielded.

Long-Range Land Attack

The Army and Marine Corps both assume that most long-range strikes will be carried out by air. They both also have attack helicopters that can perform long-range strikes. During the Cold War, the Army fielded several types of ballistic missiles, culminating in the Pershing II, which had a range of about 1,800 km (1,120 miles) and carried a nuclear weapon. After ratification of the Intermediate-Range Nuclear Forces (INF) treaty with the Soviet Union in 1988, however, the Army was required to destroy all surface-to-surface missiles with ranges above 500 km (310 miles). The United States has withdrawn from the INF treaty, and the Army is exploring new systems that would again allow it to field missiles capable of striking beyond 500 km.[14]

The Army has an inventory of ATACMS missiles, a ballistic missile with a range of up to 300 km (185 miles) in its most recent version, but it has some limitations: The ATACMS missile was originally designed to carry a large payload of cluster munitions a relatively short distance, with limited guidance, and it has been out of production for more than a decade. Although the Army has remanufactured much of its inventory to carry unitary (single) warheads guided by modern sensors, it intends to replace the ATACMS missile with the new Precision Strike Missile, which is expected to have improved capabilities and a longer range.

13. The Stinger was originally developed in the 1970s as a small, shoulder-fired missile with a correspondingly short range and small warhead.

14. The Administration announced its withdrawal from the INF treaty in August 2019, citing alleged violations by Russia.

2

Chapter 2: Options for Improving the Capabilities of U.S. Ground Forces

The Congressional Budget Office examined several approaches that the Department of Defense could take to procure and field ground-launched systems that would help U.S. ground forces respond relatively quickly to antiaccess and area-denial challenges in the Baltic and South China Sea scenarios. The U.S. military has a wide array of potential means to address A2/AD challenges in those scenarios, but CBO did not attempt to survey them all.[1] The agency focused on existing long-range systems that, with some adaptations, ground forces could use relatively quickly to address gaps in specific areas: a ground-launched land-attack cruise missile, an antiship cruise missile, and a long-range surface-to-air missile. CBO also explored an option in which DoD would purchase both an antiship cruise missile and a surface-to-air missile.

After surveying potential solutions for each mission, CBO determined that the most suitable near-term candidates for ground-launched systems are either Navy missiles intended for use in the Navy's Vertical Launch System (VLS, a standardized missile launcher that can hold and fire many different Navy munitions) or Air Force missiles that could be adapted to the Navy's VLS. As a result, CBO's options include a standardized ground launcher that would use VLS-type weapons. (See Box 2-1 for technical considerations related to launching long-range missiles from the ground.)

CBO evaluated other missiles in the U.S. inventory and determined that they are less suitable candidates for ground-launched systems. Broadly, those other missiles represent systems with older technology (some of which are being replaced by systems that CBO included), systems that have been or are being discontinued, and systems that do not have the capabilities needed for the relevant missions.

For example, the Navy's Tomahawk land-attack cruise missile, a relatively slow missile with no low-observable features, has become less effective at penetrating defended airspace, a capability that is likely to be a prominent feature of A2/AD scenarios. As a result, the Navy has been attempting to shut down the Tomahawk's production line for several years, but it keeps extending production to replace missiles that are used in combat. Similarly, the Army Tactical Missile System missile—a land-attack ballistic missile with a relatively short range, typically 150 kilometers (95 miles), though a variant with a 300 km (185-mile) range was also produced—was originally designed to disperse cluster munitions and has not been in production since 2007.[2] By contrast, the Joint Air-to-Surface Standoff Missile–Extended Range land-attack cruise missile is currently in production for the Air Force, and it incorporates many advances over previous systems—most notably, low-observable features that can assist in penetrating defended airspace.

Elements Common to All Options

To determine the number of systems that would be purchased under each option, CBO selected the Army's current Terminal High Altitude Area Defense missile system to represent the level of commitment needed to provide meaningful but limited military capabilities. The THAAD program has procured enough equipment to field seven batteries and 553 missiles—specialized systems and units that would not be spread throughout the force. An individual THAAD battery can launch at least 48 interceptors, and it includes additional vehicles for

1. In particular, CBO did not explore options that would disrupt the kill chain that enables hostile A2/AD systems to operate effectively, such as attacking sensors, communications networks, or command and control sites. Such options may be feasible but would differ from the options considered here.

2. The United States is not a party to the Convention on Cluster Munitions, but U.S. policy has deemphasized the use of those weapons. Cluster munitions, which contain many smaller bomblets, can disperse unexploded devices over large areas, leading to both military issues and humanitarian concerns. Some of the Army's ATACMS inventory is being modified to have a unitary (single) blast warhead.

Box 2-1.

Launching Long-Range Missiles From the Ground

Launching long-range missiles from the ground involves three major technical considerations: whether the missile is capable of being launched from the ground, whether vehicles can be developed to support the missile system, and whether the system can receive targeting information.

Missiles

The missiles currently used by the Air Force and the Navy often require certain environmental conditions, such as acceptable temperature or humidity ranges, to function most effectively. Ground-launched missiles might need engineering changes to cope with varying environmental conditions or the vibration caused by off-road driving.

Unlike air-launched missiles, ground-launched missiles require an additional missile stage or booster. Typically, a small rocket motor accelerates the missile to the speed and altitude its onboard engine needs to operate and fly the missile. The Navy has already successfully integrated such motors into ship-based launches of its Long-Range Antiship Missile, but they do add some cost, weight, and complexity to the missile compared with the air-launched version.

Ground Vehicles

The heaviest missile option that the Congressional Budget Office considered, the Standard Missile 6 (SM-6), weighs 1,500 kilograms (kg) per missile. A 4-cell transporter-erector-launcher (TEL) would thus need to accommodate 6,000 kg of missile payload, which is well within the payload range of existing THAAD (Terminal High Altitude Area Defense) TELs.

The Army's heaviest trucks, the M1075A1 Palletized Load System (PLS) vehicles and their derivatives, can transport payloads up to 15,000 kg. The current vehicles used in the THAAD battery carry payloads of 8 missiles on a smaller Heavy Expanded Mobility Tactical Truck A4–derived truck or 10 missiles on a larger M1075A1 PLS–derived truck. A THAAD interceptor weighs 900 kg, which suggests that missile payloads of 7,500 kg to 9,000 kg are feasible on those vehicles.

Some additional weight is also required for launch canisters, which hold and protect the missiles, and the structures that elevate and fire the missiles. The Navy's missile canisters are extremely heavy (more than 1,500 kg for the SM-6 canister) compared with typical Army missile canisters, however, so using the Navy's existing missile canisters might preclude a 4-cell TEL (which would require 12,000 kg of payload for the missiles and canisters) but would still permit a 3-cell TEL (9,000 kg of payload for the missiles and canisters). Alternatively, the Army could develop a lighter canister more in line with typical Army needs and weights.[1]

Developing TELs has not posed major technical challenges for similar programs in the past, and the THAAD program experienced no major issues with its ground vehicles. In addition, the Air Force uses a 4-cell Tomahawk missile TEL

1. In general, the difference in scale between naval weapon systems (which are fielded on ships displacing 8,000 tons to 10,000 tons) and ground weapon systems (which are fielded on vehicles weighing at most 60 tons to 70 tons) leads to different emphases on features and weight. For example, the Navy's 155-millimeter cannon fielded on its DDG-1000 guided-missile destroyers has a turret weight of over 100 tons, with additional ammunition storage and management within the ship's hull. The Army's 155-millimeter cannons are mounted on armored vehicles that weigh approximately 30 tons.

Continued

command and control and for fire control, as well as a large radar to detect and track targets. Although different missions might call for other missiles to have larger or smaller batteries, or more or fewer batteries or missiles, this level of commitment—as with THAAD—would provide at least two batteries for deployment to potential conflict zones during peacetime and would offer a significant military capability.

Each option CBO considered would feature a common core of systems, including trucks, firing batteries, and command and control systems. For all options, DoD would need to procure ground vehicles to transport and fire the missiles, as well as other support vehicles for command and control, communications, fire control, and other functions. Vehicles would be based on the family of heavy tactical vehicles (FHTV) trucks used by the THAAD batteries that the Army currently fields.

Along with procuring those vehicles, DoD would need to establish and maintain enough firing batteries, with about 100 military personnel each, to provide a significant military capability. Again, such batteries would be similar to the THAAD batteries that the Army currently fields.

Since all the options CBO considered are missiles capable of fitting within the Navy's standardized VLS cell (and have comparable dimensions, weights, power, Box 2-1. Continued

Launching Long-Range Missiles From the Ground

for its ground-launched cruise missile program, the BGM-109. Like the missiles that CBO considered, the Tomahawk uses a vertical launch system, and the United States has already demonstrated the technical capacity to develop and field such vehicles.

Targeting Information

Any missile system intended to attack targets at ranges beyond its own ability to detect them must receive targeting assistance. The United States has extensive experience in providing targeting information to land-attack missiles striking fixed targets, developed over decades of using the Tomahawk missile system in many strikes. In general, targeting fixed ground sites poses no major technical challenge; mission plans can be developed by higher-level commands and transmitted electronically to missile launchers with relative ease.

Attacking ships is a more difficult challenge, because they are mobile and time-sensitive targets. Ships move fast enough that antiship missiles (ASMs) are typically fired toward the area where target ships are predicted to be, and then the ASM's onboard sensors detect ships in that area. Except for having a time-sensitive target, however, the technical challenge of transmitting a location to attack is not significantly different from that of attacking ground sites. Integration of any ground-launched ASM system into the Navy's Cooperative Engagement Capability network, which transmits targeting information between ships, would allow for effective use of that system.

Intercepting aircraft and ballistic missiles requires constant targeting updates and sometimes radar support because they move at high speeds and can maneuver. The Naval Integrated Fire Control–Counter Air communications network allows sensor platforms, such as the Navy's E-2D airborne warning and control system aircraft, to pass targeting information to other platforms equipped with long-range missiles, such as ships or fighter aircraft. That system already works with Navy SM-6 missiles, and integrating ground-launched SM-6 missiles into the system would be the most straightforward way to use those missiles effectively.[2] An organic radar for surface-to-air missile batteries would reduce that system's dependence on external support, however, and allow it to engage in the missile defense role relatively independently, though it would still benefit from warnings about missile launches.

Systems CBO Considered

CBO met with representatives from the contractors responsible for the Joint Air-to-Surface Standoff Missile–Extended Range, Long-Range Antiship Missile, and SM-6 missile programs to discuss whether there were any likely technical impediments to producing ground-launched variants of the missiles. Each of the contractors stated that a ground-launched variant would not pose any serious technical challenge and that they are already exploring ground-launched variants of the missiles.

2. Reportedly, the Navy has already considered integrating Army ballistic missile defense assets into its Naval Integrated Fire Control–Counter Air network and believes the task to be technically feasible. See Sydney J. Freedberg Jr., "We Can Tie Army, Navy Missile Defense Networks: Navy Experts," *Breaking Defense* (February 24, 2017), https://tinyurl.com/y6kkm9ko.

and handling requirements), a common FHTV-based transporter-erector-launcher (TEL) could be developed to carry and fire all three of the missiles CBO considered. The Navy's VLS modules are far too large and heavy for use on trucks, and they include many systems that are essential on ships but would be unnecessary for ground units, such as armoring, cooling, suppressing fires, and managing the hot exhaust gases from the missiles during launch. However, the Army's existing heavy trucks are large enough to carry a pack of four lighter VLS-sized cells in a TEL configuration.

Like the THAAD batteries, the batteries in the options CBO considered would have 10 heavy trucks and about 100 personnel and would require annual operation and support costs of about $300 million per year, including overhead costs.[3] The cost to supply all batteries with ground equipment similar to THAAD ground equipment would be about $500 million. The cost of

3. A 4-cell TEL design would carry fewer missiles than an equivalent THAAD battalion if it used the same number of TELs; THAAD batteries have 8- or 10-cell TELs, allowing 48 to 60 missiles to be ready for use. As a practical matter, the military could choose between adding more TELs to the batteries or reloading TELs as needed. The costs of TELs and their associated personnel are very small compared with the cost of acquiring the missiles to arm the TELs, so budgetary constraints would be more likely to affect missile purchases than TEL purchases.

Table 2-1.

Onetime Procurement and Annual Operation and Support Costs of the Four Missile Options CBO Considered

Millions of 2020 Dollars

	Costs
Option 1	
Onetime procurement	
JASSM-ERs (550 missiles)	800
Ground equipment (7 batteries)	500
Total	**1,300**
Annual operation and support	300
Option 2	
Onetime procurement	
LRASMs (550 missiles)	1,700
Ground equipment (7 batteries)	500
Total	**2,200**
Annual operation and support	300
Option 3	
Onetime procurement	
SM-6s (550 missiles)	2,300
Ground equipment (7 batteries)	500
Missile defense radar (7 radars)	1,700
Total	**4,600**
Annual operation and support	300
Option 4	
Onetime procurement	
LRASMs (550 missiles)	1,700
SM-6s (550 missiles)	2,300
Ground equipment (7 batteries)	500
Missile defense radar (7 radars)	1,700
Total	**6,300**
Annual operation and support	300

Source: Congressional Budget Office.

JASSM-ER = Joint Air-to-Surface Standoff Missile–Extended Range; LRASM = Long-Range Antiship Missile; SM-6 = Standard Missile 6.

the missiles (or radar, if needed) would be additional and would depend on the missile (or radar) chosen (see Table 2-1).

Option 1: Purchase a Ground-Launched Joint Air-to-Surface Standoff Missile–Extended Range

Option 1 would provide U.S. ground forces with a stealthy land-attack cruise missile that is already in production and that could strike a limited number of ground targets at long ranges.

Details

For this option, DoD would procure enough ground vehicles for seven batteries, as well as 550 JASSM-ERs adapted for ground launch. Those quantities would enable the Army to deploy at least two batteries (with 24 missiles each) to potential conflict zones and four to six batteries to an actual conflict, similar to what the Army expects for its seven THAAD batteries.

The JASSM-ER is an air-launched cruise missile developed by the Air Force with low-observable features and a range of about 925 kilometers (575 miles). It has a new engine and additional fuel capacity that extend its range beyond the original JASSM's 370 km (230 miles).

To be launched from the ground, the JASSM-ER would need a booster motor to accelerate the missile to an appropriate speed and altitude to engage its turbofan engine. Such boosters are a relatively common and simple technology that the military has developed and deployed to allow other air-launched missiles to be launched from ground or naval platforms. (For example, the Navy uses a booster motor for the ship-launched variant of its Harpoon missile.) The Navy has fitted the Long-Range Antiship Missile, a missile derived from the JASSM-ER, with a booster motor to test-fire it from Navy ships, which suggests that modifying the JASSM-ER with a booster motor would be relatively straightforward.

The Air Force is currently engaged in full-rate production of the JASSM-ER, but it has ended production of the JASSM, which forecloses the possibility of purchasing that shorter-range missile in this option.

Effects

Army forces with the ability to launch JASSM-ERs from ground units could conduct long-range strikes on high-value, static ground-based targets even without air or naval support. In a Baltic scenario, Army ground forces operating without the benefit of air superiority could conduct strike missions that would otherwise not be possible. In a South China Sea scenario, if U.S. allies allowed the missiles to be stationed in their territory, the United States might be able to strike targets in mainland China.[4]

In addition to allowing strikes on Russian and Chinese targets, a ground-launched JASSM-ER could provide a deterrent effect if deployed to either theater before the onset of

4. For example, much of northern China would be within range of JASSM-ER missiles stationed in South Korea.

hostilities. During the early phases of a conflict, it could also reduce the workload of U.S. aircraft, allowing them to undertake missions other than JASSM-ER delivery.

The JASSM-ER already has sufficient standoff range to allow U.S. aircraft to fire it at relevant targets from beyond the range of Russian or Chinese air defenses. In a Baltic scenario, a ground-launched JASSM-ER could allow Army ground forces to strike targets farther behind Russian air defenses because, unlike aircraft, they could launch from within the area denied by those air defenses. But that capability would provide a relatively small direct benefit to the United States in a conflict under way.

Like most land-attack cruise missiles, the JASSM-ER is intended to attack a few high-value fixed sites. Typically, the United States uses cruise missile and other attacks as part of an opening salvo intended to destroy enemy air defenses, thus allowing U.S. aircraft to strike a wide array of militarily relevant targets. Modern Russian and Chinese air defenses are mobile systems mounted on trucks, however, and they are unlikely to remain in a location long enough for the United States to detect them, plan a strike mission, and execute that mission. (It takes a JASSM-ER roughly an hour to reach a target that is near the edge of its range.) Although the theater has other fixed targets, ground-launched JASSM-ERs could not effectively attack the most urgent threats in Baltic scenarios.

The Army has already begun to develop a different missile, the Precision Strike Missile, intended as a tool to suppress enemy air defenses. Although still early in development, the Army's plans are for a missile with a range of up to 499 km (310 miles), fired from existing Multiple-Launch Rocket System and High-Mobility Artillery Rocket System launchers, with warheads and seekers optimized for detecting and destroying enemy radars and mobile vehicles. If the Army developed and fielded this system, it would perform the highest-priority mission for long-range missiles envisioned for a Baltic scenario.

Another consideration for this option is that the Intermediate-Range Nuclear Forces treaty, from which the United States has withdrawn, prohibited parties from fielding ground-launched cruise missiles with a range between 500 km (310 miles) and 5,500 km (3,420 miles). The JASSM has a range of 370 km (230 miles) and would thus have been permitted, but the JASSM-ER and any ground-launched version, with a range of 925 km (575 miles), would have been prohibited. Fielding such missiles might reduce the likelihood of a future agreement between the United States and Russia to restrict intermediate-range weapons, although it might also perform a role similar to that of the Pershing II and ground-launched cruise missile systems in the 1980s, which helped convince the Soviet Union that it would gain by agreeing to restrict such missiles.

Costs

CBO estimates that the cost to purchase and equip seven batteries of ground launchers with 550 JASSM-ERs would be about $1.3 billion (in 2020 dollars; see Table 2-1). The cost to operate and sustain that force would be about $300 million each year, assuming that the system would require expanding the size of the Army to field additional units rather than having it replace another system. (See the appendix for a discussion of how CBO developed its cost estimates.)

Option 2: Purchase a Ground-Launched Long-Range Antiship Missile

Option 2 would provide U.S. ground forces with a stealthy antiship cruise missile that is currently in production and that could attack ships at long ranges.

Details

For this option, DoD would procure enough ground vehicles for seven batteries, as well as 550 LRASMs adapted for ground launch. Those quantities would provide at least two batteries (with 24 missiles each) to deploy to potential conflict zones in peacetime and four to six batteries for an actual conflict.

The LRASM is an air-launched cruise missile developed for the Air Force and Navy and based on the JASSM-ER. Like that missile, it includes low-observable features, but it has a different seeker (designed to find ships) and, like the JASSM-ER, could have a range of up to 925 km (575 miles).[5] The LRASM is intended to search for naval targets autonomously and is also capable of receiving targeting information from external sources, including

5. The Navy describes the LRASM as having a range of more than 200 nautical miles (370 km), but the actual range of the missile is classified. Public sources assume that because the LRASM is based on the JASSM-ER, it has a similar range; other sources acknowledge that changes in the size of the warhead or sensor package may have resulted in a missile with a shorter range. The JASSM-ER itself is based on the 370-km-range JASSM but with changes to that missile's engine and fuel supply. The exact range of the LRASM does not affect CBO's findings, however; any range between the Navy's lower bound and the JASSM-ER's range would provide similar capabilities.

other LRASMs. To make the missile capable of being launched from a ship, the Navy has begun developing a variant of the LRASM with a booster motor attached to accelerate the missile to an appropriate speed and altitude to engage the turbofan engine of the primary missile.

The Navy is currently purchasing a limited quantity of air-launched LRASMs as an interim solution to meet its goal of acquiring a new antiship cruise missile. Under this option, the Army would purchase the Navy's variant of the missile for ground forces.

Effects

Russian naval forces do not present a significant threat in a Baltic scenario, and it is unlikely that ground-launched LRASMs would give the United States any additional capabilities in such scenarios.

If Army forces could launch LRASMs from ground units on bases accessible to the United States at the beginning of any potential conflict in the South China Sea, they could deny Chinese surface warships access to much of the theater. In a scenario in which the United States attempted to seize and defend the militarized islands in the South China Sea, moving ground-based LRASM launchers to any seized islands could prevent Chinese forces from operating surface warships or commercial shipping within the South China Sea.

Ground-based LRASMs would also assist the United States if it chose instead to impose a blockade against Chinese shipping in a South China Sea scenario.[6] Although Chinese air, naval, and missile forces would make a traditional close blockade of Chinese ports a difficult military task, the geography of the South China Sea requires Chinese shipping to pass through several choke points to access overseas markets (see Figure 2-1).

- **Northern routes that head toward North America.** These routes pass by three treaty allies of the United States—Japan, South Korea, and Taiwan. The United States has many bases in this region capable of projecting power into the surrounding waters.
- **Central routes that pass through the Philippine archipelago.** Chinese claims to the South China Sea that conflict with Filipino claims to the area are a possible cause of a South China Sea conflict. The United States has a mutual defense treaty with the Philippines, and the Filipino government allows the United States to operate from five air bases there, one of which (Antonio Bautista Air Base) is near one set of Chinese militarized islands.
- **Southern routes that head toward the Indian Ocean.** The Strait of Malacca is one of the busiest shipping channels in the world. The United States has a long-standing defense relationship with and Navy presence in Singapore, which is near the Strait. Other routes to the Indian Ocean pass through Indonesian waters, however, and the United States does not have a significant defense relationship with Indonesia.

With sufficient cooperation from local allies, the United States could enforce a distant blockade on Chinese shipping by stationing air and naval forces around those choke points. Such a strategy would face several constraints, however: First, Indonesia is not an ally of the United States and would not be expected to help blockade the southern shipping routes. Second, some allies might choose not to participate in any conflict. Third, some of the bases that the United States would need to enforce a blockade are themselves credibly threatened by Chinese attacks.

Ground-based LRASMs could help alleviate these problems. If located at sites in the Philippines and Singapore, the LRASM has a long enough range to threaten Chinese ships attempting to use southern routes toward the Indian Ocean. The LRASM's range is also long enough that the United States might be able to compensate if an ally declined to allow the use of its territory during a conflict. For example, the United States could locate LRASMs on Okinawa and Luzon if Taiwan declined to allow the use of its territory. LRASMs located in the territory of U.S. allies and possible partners might deny Chinese access to sea lanes (see Figure 2-2).

Although the central and northern routes are well within range of potential Chinese counterattacks, the presence of ground-based launchers in key locations such as Okinawa could deny China the use of those shipping lanes, even if its forces executed effective attacks against other U.S. assets in the region. Ground-based launchers are intrinsically more difficult to attack and destroy

6. For a detailed technical analysis of the feasibility of using ground-launched ASMs to enforce a blockade on China, see Terrence K. Kelly and others, *Employing Land-Based Anti-Ship Missiles in the Western Pacific* (RAND Corporation, 2013), www.rand.org/pubs/technical_reports/TR1321.html. CBO's discussion of the possibilities for enforcing such a blockade relies heavily on that report.

Figure 2-1.

Major Chinese Sea Lanes

Source: Congressional Budget Office.

than fixed infrastructure such as air bases, which may be vulnerable to cruise or ballistic missile attacks.

Costs

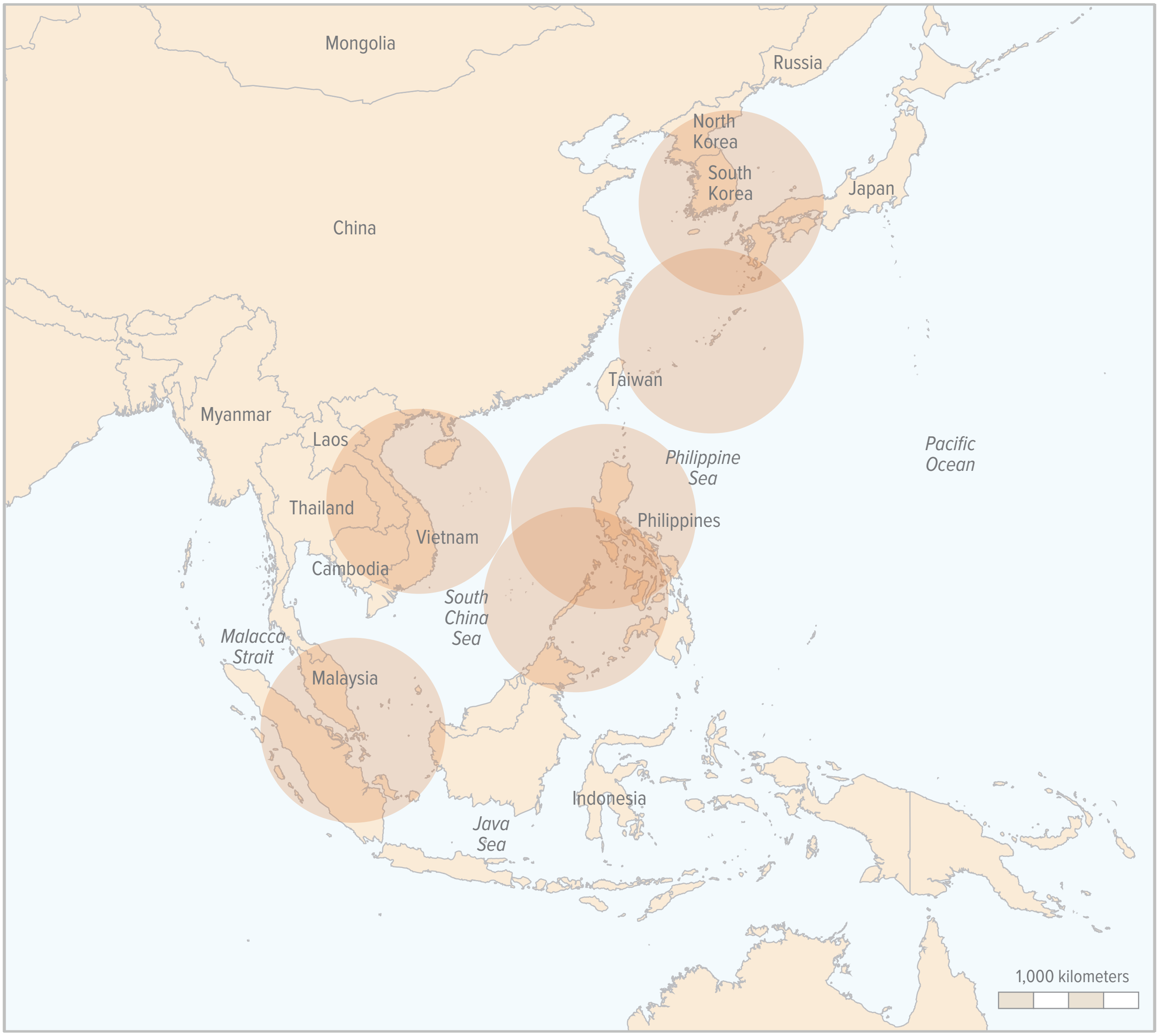
CBO estimates that the cost to purchase and equip seven batteries of ground launchers with 550 LRASM missiles would be about $2.2 billion, and the cost to operate and sustain that force would be about $300 million each year (see Table 2-1 on page 20).

Option 3: Purchase a Ground-Launched Standard Missile 6

Option 3 would provide U.S. ground forces with a surface-to-air missile that is in production and that could destroy aircraft, cruise missiles, and some shorter-range ballistic missiles at long ranges. The missile also has a limited ability to attack ships.

Figure 2-2.

Potential Effects of Ground-Launched Antiship Missiles on China's Access to Sea Lanes



Source: Congressional Budget Office.

The exact range of the Long-Range Antiship Missile (LRASM) has not been publicly disclosed. The shaded circles show a notional range of 600 km, roughly the midpoint between the publicly disclosed lower bound of the missile (370 km) and the range of the Joint Air-to-Surface Standoff Missile–Extended Range, or JASSM-ER, that the LRASM is based on.

Details

For this option, DoD would procure enough ground vehicles for seven batteries, seven THAAD-like radars, and 550 SM-6s adapted for ground launch. Those levels would be sufficient to provide at least two batteries (with 24 missiles each) to deploy to potential conflict zones and four to six batteries for an actual conflict.

The SM-6 is a Navy surface-to-air missile with a range of at least 240 km (150 miles) that is designed to destroy aircraft, cruise missiles, or ballistic missiles at long ranges.[7]

7. The Navy has not published a range for the SM-6. However, numerous public sources state that the SM-6's range is greater than 240 km (150 miles).

In addition, the Navy has tested the SM-6 as an antiship missile in a potential secondary role (although its warhead, at 140 pounds, is much smaller than the 1,000-pound warhead on the LRASM, and CBO did not consider the SM-6 in the antiship role).[8] As a Navy missile launched from warships, the SM-6 is already capable of being launched from surface platforms. By comparison, the Army's Patriot system has a range of 100 km (60 miles) or less, depending on the type of missile and role. The Army's THAAD system, although it has a longer range, is only for ballistic missile defense, not defense against aircraft or cruise missiles.

The SM-6 has been designed to operate with the Navy's Naval Integrated Fire Control–Counter Air system to allow it to receive targeting information from aircraft or ships other than the ship firing the missile. This ability is particularly important for a missile with a range as long as the SM-6's because the limitations of the radar horizon prevent the launching ship from detecting many aircraft or cruise missiles at the ranges at which the SM-6 is capable of engaging targets. The Navy has already demonstrated that an E-2D airborne warning and control system (AWACS) aircraft can direct an SM-6 missile to destroy a target beyond the range at which its launching ship could detect the target.

It may be undesirable to have ground-launched SM-6 batteries wholly reliant on external targeting, however. Unlike land-attack or antiship missiles, most surface-to-air missiles cannot acquire their own targets, and not having an organic radar system would make the system unnecessarily dependent on other forces.[9] To provide the most benefit, such batteries would need a radar for air defense missiles that could perform both air and missile defense, comparable to the THAAD radar (which costs about $245 million per radar). CBO included such a radar for each battery in this option.

Effects

With the ability to launch SM-6 missiles from ground units, Army forces could deny Russian forces many advantages in a Baltic scenario:

- Russian aircraft would not be able to operate freely beneath their own protective A2/AD air defense system and could not subject U.S. ground forces to an unfettered aerial attack.
- Russian forces would not be able to provide AWACS support to their own air forces and thus would not be able to use the extended range of their surface-to-air missiles against most targets other than the North Atlantic Treaty Organization's AWACS aircraft.[10] Without AWACS support, Russian aircraft would also be greatly inhibited in their ability to conduct counterair campaigns against NATO aircraft.
- With a reduced Russian air defense threat, U.S. aircraft could mount a successful campaign to suppress enemy air defenses against Russian SAMs and other air defenses, freeing the United States to use its own AWACS support. In particular, the extremely long ranges of Russian SAMs would be largely irrelevant without AWACS support, as it would be impossible for them to identify targets at long range.
- With a successful suppression of enemy air defenses campaign and AWACS support, U.S. aircraft could mount a counterair campaign and support U.S. ground forces in combat against Russian ground forces.
- Russian artillery would be significantly less effective if it could not use aerial assets to locate appropriate targets. The more rapidly the United States could

8. Technically, almost all members of the Standard Missile family have that capability, as did their predecessor systems. All those missiles had a semi-active radar homing mode, in which the missiles would home in on reflected radar signals, allowing them to attack ships if those ships were illuminated by an appropriate fire control radar. With the SM-6, however, the Navy has chosen to emphasize this capability—possibly because the SM-6, unlike prior systems, also has a fully active seeker that does not require illumination by a fire control radar. As a result, it can be used in an antiship role with fewer limitations than earlier systems, which were limited by the radar horizon to much shorter engagement ranges.

9. An organic air defense radar could acquire targets above the radar horizon, which would be a much shorter range than the full range of the SM-6 missile for most aircraft and cruise missiles, thus limiting the system's capability. But it would be the same range for ballistic missile defense because the high trajectory of ballistic missiles makes radar horizon considerations less relevant.

10. Very-long-range SAMs such as the SM-6 and the Russian S-400 system require external targeting assistance (typically from AWACS aircraft) to be able to take advantage of their range. The effectiveness of those systems' own ground-based radar is limited by the radar horizon and the altitude of potential targets. For AWACS aircraft to perform their mission effectively, however, they must fly at high altitude and actively emit radar signals, making them easy to detect at a distance.

begin an air campaign, the more rapidly it could deny Russian forces useful targeting information.[11] In addition, the United States could use tactical aviation to assist in destroying Russian artillery units.

Having the SM-6 available for ballistic missile defense could also assist U.S. forces in a Baltic scenario. If Russian forces attempted to strike NATO air bases, command and control nodes, or logistics stockpiles with their large inventory of short-range ballistic missiles, SM-6 missiles could reduce the risk of those strikes being successful.

If Army forces could launch SM-6 missiles from ground units, they could deny Chinese forces several advantages in a South China Sea scenario:

- If the United States attempted to seize and defend the militarized islands in the South China Sea, moving ground-based SM-6 launchers to any seized islands would reduce China's ability to use the surrounding airspace to threaten U.S. forces with air or cruise missile attacks. The SM-6 does not have sufficient range, however, to fully prevent Chinese air forces from acting within the theater.

- Similarly, the United States could use ground-based SM-6 launchers to defend any seized islands against counterattacks. Importantly, that defensive capability would allow more vulnerable assets, such as Navy ships, to remain at a safer distance from the Chinese mainland.

- Even if the United States did not move ground-based SM-6 launchers to any seized islands, the sheer volume of Chinese cruise and ballistic missiles would make additional air and missile defense units in the theater valuable. The United States has a limited number of those assets, so any additional assets that allowed it to defend more locations, with additional redundancy at key sites, would be valuable. In particular, the credible fear of retaliation from Chinese ballistic missile attacks is often considered a vulnerability of the U.S. alliance system in East Asia, which is largely composed of bilateral agreements with the United States rather than a collective defense treaty such as NATO. The ability to reassure U.S. allies who are not directly involved in any dispute in the South China Sea (such as Japan or Korea) that they would be defended if they allowed the United States to use bases in their territory would be highly valuable.

- The SAM systems that the United States currently has are not oriented to providing wide-area air defense for its regional allies.[12] The ability to position credible wide-area air defenses in the theater before hostilities occur would be a useful deterrent and would reassure U.S. allies that their territory would be less vulnerable to Chinese retaliatory strikes. For example, three SM-6 batteries located within the Philippines could provide reasonable air defense coverage for the entire country.

Although the SM-6's secondary mission—performing antiship roles—could help defend against Chinese naval forces, its range is not sufficient to fully prevent Chinese naval forces from acting in the South China Sea, and that role is limited compared with the capabilities of missiles designed for the antiship role.

Arguably, this option's value is less relevant in a South China Sea scenario than in a Baltic scenario because the capability it offers—long-range air defense—would supplement the SM-6 missiles on Navy ships that would be deployed in the region during a conflict. In a Baltic scenario, however, long-range air defense is a new capability that existing Patriot or THAAD batteries do not have.

Costs

CBO estimates that the cost to purchase and equip seven batteries of ground launchers, seven THAAD radars, and

---

11. Without accurate targeting information, Russian forces could use their traditional artillery tactics—including area fire, which involves firing enough ordnance into a grid to be reasonably sure of damaging everything within that area. Such tactics impose a huge logistics burden because they expend much larger quantities of ammunition than targeted strikes do; that burden also slows a force's advance considerably and presents many vulnerable targets, such as ammunition supply areas, the trucks moving that ammunition, and the zones from which the artillery fires. Counterbattery fire is significantly easier against opponents that fire more often because counterbattery radars detect the artillery shells fired and extrapolate the location of the firing platform from the shells' ballistic trajectories.

12. The Army's Patriot missile batteries effectively provide point-defense coverage of military installations against ballistic missile attacks. Defending the entire territory of a U.S. ally—or a substantial portion of it—against missile attacks requires longer-range missiles. At present, that requires stationing either a THAAD battery (of which the Army has a limited supply) or a Navy missile defense warship (which could be highly vulnerable to cruise missile attack in a South China Sea scenario) near that ally. THAAD is not intended to provide air defense.

550 SM-6s would be about $4.6 billion, and the cost to operate and sustain that force would be about $300 million each year (see Table 2-1 on page 20).

Option 4: Purchase Both a Ground-Launched LRASM and an SM-6

Option 4 would provide U.S. ground forces with a mix of antiship cruise missiles and surface-to-air missiles that are currently in production and that could destroy ships, aircraft, cruise missiles, and some ballistic missiles at long ranges.

Details

This option would combine elements of Options 2 and 3, taking advantage of the common launcher. DoD would procure enough ground vehicles for seven batteries and seven THAAD radars but twice the number of missiles: 550 LRASM missiles adapted for ground launch and 550 SM-6 missiles adapted for ground launch. Those quantities would be sufficient to provide at least two batteries (with 24 missiles each of either or both types) to deploy to potential conflict zones and four to six batteries for an actual conflict.

Because the ground-launched JASSM-ER offers minimal benefits compared with LRASMs and SM-6s, this option would not include any JASSM-ER purchases. If the United States decided that a ground-launched cruise missile capability was valuable, however, it could incorporate that capability with the missiles this option includes.

The ground-launch equipment for Navy missiles, including the LRASM and SM-6, can be designed to the common standard that the Navy uses in its VLS launchers, so the missile loads of the ground-based launchers could be tailored to the needs of a particular theater or threat assessment. Since both the LRASM and the SM-6 would be useful in a high-end conflict, the Army could maintain an inventory of both types of missiles to deploy as appropriate. For example, a South China Sea scenario might call for a mix of missiles, but a Baltic scenario might require only the SM-6. Purchasing both types of missiles would offer the benefits of each.

Effects

With the ability to launch both LRASMs and SM-6s from ground units, Army forces could assist in both Baltic and South China Sea scenarios, as discussed in Options 2 and 3.

In a Baltic scenario, Army units would probably use SM-6s, which would provide the same benefits as in Option 3: denying Russian air forces the ability to operate freely beneath their own air defense umbrella, threatening Russian AWACS, supporting a U.S. SEAD campaign, and defending U.S. infrastructure from Russian ballistic missile attacks.

In a South China Sea scenario, Army units would probably use a mix of LRASMs and SM-6s, which would provide the same benefits as in Options 2 and 3. Those include denying use of the South China Sea to Chinese surface vessels, defending captured militarized islands from a counterattack, and enabling a distant blockade of Chinese shipping, as well as providing additional ballistic missile defenses for key U.S. bases.

Costs

CBO estimates that the cost to purchase and equip seven batteries of ground launchers, seven THAAD radars, 550 LRASM missiles, and 550 SM-6 missiles would be about $6.3 billion, and the cost to operate and sustain that force would be about $300 million each year (see Table 2-1 on page 20).

The cost of Option 4 would be less (about $540 million less in purchases of ground equipment and $300 million less in annual operating costs) than the combined cost of Option 2 and Option 3, because the Army would buy and operate seven batteries of ground equipment instead of the total of 14 batteries encompassed by the combination of Option 2 and Option 3. The batteries under this option would be more flexible than under either of the single options because they could use either type of missile. But with seven batteries, the Army would not be able to deploy as many missile launchers under this option as it could if it pursued both Option 2 and Option 3.

Appendix: How CBO Developed Its Cost Estimates

In this report, the Congressional Budget Office used three methods to develop the costs for missiles and radars, ground equipment, and annual operation and support.

Costs for Missiles and Radars

The missiles in CBO's options are all currently in production, and CBO used their known production costs, as documented in the Department of Defense's budget materials. For Options 3 and 4, CBO used the cost of the Terminal High Altitude Area Defense (THAAD) program's missile defense radar as a proxy for the cost of a missile defense radar; the THAAD radar is also currently in production.

Costs for Ground Equipment

CBO relied on budget documentation for the THAAD program, the most recent U.S. weapon system to require development of comparable ground vehicles for large, sophisticated ground-launched missiles. The cost of producing ground equipment for seven batteries of missile launchers was displayed separately in budget materials from the other components of the THAAD program. CBO's options would all require ground equipment very similar to that of the THAAD program, making it the most relevant program for comparison.

Annual Operation and Support Costs

For this report, CBO used the same methodology that it did in *The U.S. Military's Force Structure: A Primer* (www.cbo.gov/publication/51535). That methodology provides estimated per-person costs for military personnel, including the costs of providing essential support functions, the costs of operating and maintaining units, and the costs incurred by defensewide agencies such as the Defense Health Program.

Each option in this report calls for seven batteries. Existing THAAD batteries—the closest analogue for such launchers in today's force—require about 100 military personnel. CBO estimated that those 100 personnel would require an additional 400 military personnel to support them, for a total of about $300 million per year in annual operation and support costs.

List of Tables and Figures

Tables

Figures

About This Document

This Congressional Budget Office report was prepared at the request of the Chairman and Ranking Member of the Senate Armed Services Committee. In keeping with CBO's mandate to provide objective, impartial analysis, the report makes no recommendations.

Adam Talaber prepared the report with guidance from David Mosher and Edward G. Keating. Robert Reese and F. Matthew Woodward provided helpful comments, as did Eric Lindsey of Northrop Grumman, David Shlapak of the RAND Corporation, and Lloyd Thrall of the University of Colorado, Boulder. (The assistance of external reviewers implies no responsibility for the final product, which rests solely with CBO.) Adebayo Adedeji fact-checked the report.

Jeffrey Kling and Robert Sunshine reviewed this report. The editor was Rebecca Lanning, and the graphics editor was Robert Rebach. The report is available on CBO's website (www.cbo.gov/publication/56068).

CBO continually seeks feedback to make its work as useful as possible. Please send any comments to communications@cbo.gov.

Phillip L. Swagel
Director
February 2020